MINUTES OF THE NASA ENVIRONMENTAL COMPATIBILITY RESEARCH WORKSHOP
Held July 7-9, 1998

At the Monterey Plaza Hotel, Monterey, CA

The following persons attended this Workshop.

First	Last Name	Company
Krish	Ahuja	Georgia Institute of Technology
Richard	Altman	Pratt & Whitney
Donald	Anderson	NASA Goddard
Richard	Antcliff	NASA Langley
Chris	Arman	City of Chicago/O'Hare Airport
Howard	Aylesworth	Aerospace Industries Association
David	Bowles	NASA Langley
Gerald	Brines	Allison Engine Company
Ray	Brown	Delta Airlines
Lisa	Chang	EPA
Adina	Cherry	SAIC
Kestutis	Civinskas	NASA Lewis
John-Paul	Clarke	MIT
Thomas	Connor	FAA
Charles	Cowan	Cutler & Stanfield
Robert	Cuthbertson	The Boeing Company
Thomas	Davis	NASA Ames
Ruben	DelRosario	NASA Lewis
Dallas	Denery	NASA Ames
Barbara	Dillon	SAIC
Willard	Dodds	GE Aircraft Engines
John	Dodge	Allied Signal
Sam	Dollyhigh	NASA Langley
Michael	Dudley	NASA Ames
Doug	Dwoyer	NASA Langley
Dick	Dyer	CA DOT
Tony	Fiorentino	Pratt & Whitney
Phil	Fowlie	United Airlines
Don	Galbraith	Galbraith Associates
Jarvis	Gantt	Univ. of TX-Applied Research Labs
Christine	Gerencher	Landrum & Brown
Glenn	Gilyard	NASA Dryden
Philip	Gliebe	GE Aircraft Engines
John	Graham	Los Angeles International Airport
Oren	Hadaller	The Boeing Company
William	Haller	NASA Lewis
Peter	Hart	Allison Engine Company
Robert	Howard	AEDC/Sverdrup
Aubre	Howell	Northrop Grumman
Jim	Humphries	Sacramento International Airport

Lynae	Jacobson	SEATAC Airport
Rod	Jago	SAIC
Betty Ann	Kane	National Org. to Insure Sound Environment
Rich	Kassel	National Resources Defense Council
Barry	Kiel	AFRL/PRTC
David	Koert	Wichita State U.-National Institute of Aviation Rsch
Richard	Lawrence	NASA Goddard
Duc	Le	US DOE
Ellina	Levina	Center for Clean Air Policy
Anita	Liang	NASA Lewis
Dick	Linn	Dallas-Ft. Worth Airport
James	Littleton	FAA
Gary	Machles	GE Aircraft Engines
Tom	Maloney	Dunacs/NASA Lewis
Bill	Marx	FAA
Doug	Mathews	Pratt & Whitney
Peter	McCallum	NASA HQ
Richard	Miake-Lye	Aerodyne Research Inc.
Nicholas	Miller	Harris, Miller, Miller & Hanson
John	Morgenstern	Lockheed Martin
Louise	Mudd	FAA/TRW
Frank	Murray	SAIC Consultant
Kevin	Nesbitt	CALSTART
Cindy	Newberg	EPA
Jim	Ohi	National Renewable Energy Lab
Charlie	Parente	Northrop Grumman
John	Pehrson	Camp Dresser & McKee Inc
David	Picasso	NASA Ames
Clemans	Powell	NASA Langley
Carol	Quinn	NASA Lewis
Ron	Ray	NASA Dryden
Lisa	Reuss	SAIC
Karen	Robertson	Dallas-Ft. Worth Airport
John	Rohde	NASA Lewis
Carol	Russo	NASA Lewis
Naseem	Saiyed	NASA Lewis
David	Schein	Northrop Grumman
Arun	Sehra	NASA Lewis
Fredric	Schmitz	Univ. of Maryland
Paul	Senick	NASA Lewis
Ben	Sharp	Wyle Laboratories
Belur	Shivashankara	The Boeing Company
Brian	Smith	NASA Ames
Chuck	Smith	NASA Ames
Glenn	Smith	NASA HQ
Chris	Snyder	NASA Lewis
David	Stephens	NASA Langley
Gary	Stowell	San Jose International Airport

Don	Sutkus	The Boeing Company
Mary	Vigilante	Synergy Consultants, Inc.
Ian	Waitz	MIT
Donald	Weir	Allied Signal
Howard	Wesoky	NASA HQ
Chowen	Wey	NASA Lewis
Bill	Willshire	NASA Langley
Keith	Wilschetz	Landrum & Brown
Ted	Woosley	Landrum & Brown
Jia	Yu	BFGoodrich Aerospace
Isam	Yunis	NASA Lewis
Rick	Zelenka	NASA Ames

Welcome and Introductions
Schedule and Logistics
Agenda for Workshop III

Mr. Frank Murray opened the meeting by welcoming all attendees and mentioning that the major theme of this Workshop was "Feedback." He reviewed the Workshop agenda and the process to be followed at this meeting. He mentioned that the three "Interest" groups, Industry, Operators, and NGO/Communities would be meeting Wednesday to begin the "Feedback" report. Mr. Murray briefly reviewed the four questions each group was scheduled to address. (These questions are included in the agenda). He stressed that serious consideration should be given to the question of the continuing dialogue to ensure that the recommendations coming from the workshops are not forgotten after the workshop process is completed. He reviewed changes to the agenda, meeting logistics, and other general housekeeping functions then turned the meeting over to Howard Wesoky.

Update on NASA Planning Process

Mr. Wesoky discussed the history of the ECoA Team and charter and the motivations for its creation. White House Policy, the European Commission, the Kyoto Protocol, and the "Three Pillars" Goals, specifically the goals for reduction in aircraft noise and emissions were also discussed. He stated that the three-workshop process was designed to bring NASA together with industry, universities, government agencies, and non-governmental organizations in order to accomplish the goals mandated by NASA. He also stated that not all environmental goals have purely technical or engineering solutions, and that strategies such as pollution credits should not be discounted. Mr. Wesoky discussed the Aeronautics and Space Transportation Technology Advisory Committee (ASTTAC) and its members, as well as the workshop process and objectives. He summarized that there is a strong mandate for NASA to initiate significant investment toward the "Three Pillars" emissions and noise goals. As a result of NASA's mandate, fulfillment of the Three Pillars goals became the workshop objective. Mr. Wesoky then introduced Mr. Dave Stephens to brief the participants on what the Noise research program was accomplishing.

Please note, copies of the briefings summarized in these Minutes are available on the EcoA website at http://www.hq.nasa.gov/office/aero/oastthp/programs/encompat/encompat.htm.

Noise Environment

Dave Stephens presented the noise perspective. He briefly reviewed the Pillar Goals with the Workshop attendees and the timing associated with attaining the goals. He reviewed the benefits associated with achieving the goals from the perspective of a single event noise level and from a community noise exposure event. The benefits resulting include the following: 1) aircraft noise would be confined within airport boundaries; 2) the environment would be curfew-free with unconstrained operations and growth; and 3) the US would realize improved competitiveness. Mr. Stephens then reviewed the Gap Analysis requirements, areas of concentration, and potential contributions. The four principal elements, engine systems, airframe systems, modeling and integration, and airspace operation, as well as the corresponding reduction goals of the environment program were briefly discussed. He then presented the ECoA strategy with related needs, concepts, and goals and resulting Roadmaps developed to achieve them. The Roadmaps and charts of Mr. Stephen's presentation can be found on the NASA ECoA website under the Monterey Workshop III.

Emissions Environment

John Rohde updated the group on the emissions perspective. His presentation included CO_2 and NO_x reduction waterfalls with AST technologies, ECoA initiatives and notional concepts. He also discussed zero-emissions 777-type aircraft, fuel cell/electric motor/ mini-fan propulsion systems, and revolutionary concepts for both carbon- and non-carbon-based fuel systems. Roadmaps were presented which included goals for 10, 25, and 30-40 years. The technology challenges in achieving the goals were then identified for the group. Mr. Rohde then reviewed potential level 2 plans for propulsion, airframe, and ground and flight operations, which supported achievement of the goals. The impacts of emissions metrics definition were also discussed. Mr. Rohde's briefing can be found on the NASA ECoA website.

Los Angeles International Airport (LAX) Master Plan

Jack Graham led the discussion on the LAX master plan with the assistance of Keith Wilschetz and John Pehrson. Although the LAX Master Plan is still in development, it provides a sound technical basis for addressing a variety of issues associated with airport growth. The issues discussed during the presentation include the regional economic importance of LAX, LAX activity levels, local air quality, and LAX's national importance. Graham stated that LAX is the busiest cargo and passenger link to Asia in the continental US, and is vital to California's economy. Over the past several years, passenger demand has increased by 10 million people, and cargo tonnage increased by 24 percent. Further increases are predicted for the near future. Resulting unrestrained growth would have a significant impact on not only the environment, but also on automobile and traffic congestion in the vicinity of the airport, as well as increasing passenger activity that will result in displacement of connecting passengers. The LAX Master plan provides for planned orderly growth; minimization of adverse environmental impacts; improved airport efficiency; and enhanced land use compatibility with the adjacent communities. The LAX Master plan will analyze air quality impacts associated with aircraft, ground support equipment, stationary facilities, motor vehicles, and construction equipment, and attempts to minimize the environmental impacts of emissions. Graham also stated that while other area airports will need to be expanded to meet the anticipated increase in passenger demand and cargo shipments, there are no plans to build a new airport. He also stated that many other airports face the same problems and concerns regarding expansions and growth as LAX, but do not publicly voice these concerns to avoid being highlighted. In closing he stated that it is imperative that

these problems be addressed to ensure that air quality regulations do not effectively handicap the airport plans to meet increasing passenger and cargo demands.

Further discussion among the participants resulted in variety of questions. It was mentioned that while there are no hard numbers on the impacts of LAX on Los Angeles air quality, in the Los Angeles basin, aircraft are responsible for approximately 10%, while in the vicinity of the airport the number can be as high as 50%. The master plan also calls for minimization of vehicle usage on the airport, and for transportation to the airport. Mr. Dick Linn inquired as to the plans for subway or metro system to the airport. The Master Plan calls for a metro link to the airport. The issue of noise impact on the surrounding community was also mentioned. The master plan does take noise into consideration by calling for runways to be set so that noise contours are more advantageously situated.

Following the LAX briefing, the noise and emissions breakout groups formed for a series of presentations and discussions.

Breakouts

Noise Breakout Group

Bill Willshire opened the Noise Breakout session with an overview of the NASA Noise-related Programs.

Existing NASA Program Overview

Mr. Willshire provided a thorough overview of noise technologies, in relation to the Advanced Subsonic Technology Noise Reduction Program. He began by showing that the program drivers were integrated, including environmental concerns, enhanced marketability, and increased capacity. Mr. Willshire reviewed the Level I Roadmap and milestones and noted the sub-elements of the program—engine noise reduction, interior noise reduction, airframe noise reduction, nacelle aeroacoustics, and community noise impacts. An important aspect of the program is that a successful steering committee and technical working group were both formed to involve industry in program planning. He covered some of the tests involved in noise reduction like the fan broadband noise test and the low turbulence pressure tunnel high-lift airframe noise experiment. He discussed some of the technologies being utilized for noise reduction, such as computational fluid dynamics for airframe analysis; and microphone arrays for measurement of noise. Mr. Willshire concluded that the AST program is a result of an extensive NASA inter-center, FAA, and industry partnership and that it has reached its interim objectives and is now reaching further. Mr. Willshire's entire presentation is contained on the NASA ECoA website.

Advanced Propulsion Concepts (Selected)

Dr. Ian Waitz of MIT presented selected Concepts of Advanced Propulsion, beginning with an overview of the current opportunities for improvement in this area. The areas that can be improved include materials for greater durability, strength/weight ratios, new and better thermodynamic cycles, new and better engine architectures, and utilization of different or non-hydrocarbon based fuels. One of the concepts of advanced propulsion he mentioned was aspirated counter-rotating compressors. Some of the advantages of this turbofan include much lower production cost, lower fuel burn, shorter engine, lower engine weight, and low noise. The

other area of advanced propulsion is in micro-scale opportunities and in micro electric mechanical systems (MEMS). Dr. Waitz stated that although there is currently no working engine, MEMS-based thermal engines appear both promising and useful. There are potential applications in propulsion, power generation, microrocket engines, among other areas. In closing, he stated that the further development of MEMS technology presented many challenges and opportunities, and that there was a high risk coupled with a big reward.

Active Noise Control Vision: 2007-2022

Isam Yunis, NASA Lewis, briefed the Noise Group on the Active Noise Control (ANC) reality based goals and status of those goals. He discussed different methods of ANC like active engine walls and active actuators along engine walls and stators. Mr. Yunis listed some of the technologies to achieve those goals like smart materials and jet instability wave control and concluded with the visions for both 2007 and 2022.

Airframe Noise Sources

Dr. Belur Shivishankara of Boeing spoke about the major sources of noise found on airframes. The leading edge, flap edge, landing gear, and the interaction of the jet flap are the leading contributors of airframe noise. Any increase in the size of the wing results in an increase in the noise level of the airframe during approach and landing. He mentioned that Boeing conducted extensive tests in 1992-93 to determine the major contributors to airframe noise. Now that they have identified these sources, work has begun on developing supression techniques. He noted that Boeing believes that you can reduce airframe noise by approximately 2 or 3 dB, perhaps more. In closing, he stated that there is still more work that needs to be done to determine the most effective methods of noise suppression for airframes. The slides shown during the presentation contain information proprietary to Boeing, and will not be posted on the website.

Active Control of Aircraft Noise in the Community

Mr. Ben Sharp of Wyle Laboratories presented his work in active noise. Mr. Sharp began his presentation by stating that low-frequency noise from ground run-up operations is a major source of community annoyance. This occurs most commonly at night, when the majority of maintenance work takes place. The current solution, ‘hush-houses’ are expensive and inconvenient, and are not suited to airports with only localized problems. He stated that Active Noise Control (ANC) is based on the interference that occurs when two coherent sound waves are combined. This is achieved by means of a secondary noise source that is used to generate sound in anti-phase to that which is created by the unwanted noise. This results in an overall reduction in the noise level. ANC is an available solution to the noise reduction problem. ANC can be used either for global noise reduction by placing the control source near the source of the unwanted noise, or for local control by placing the control source at a distance from the aircraft in a location where noise levels are lower and can be easily generated by artificial sources. Test results indicate that the system does work—a reduction of 5-10 dB has been achieved in an area of over 5000 sq. meters. A fully functioning prototype will be available by Fall 1998 for demonstrations.

Aircraft Noise and Land Use Planning

Mr. Nick Miller discussed Aircraft Noise and Land Use Planning. He began by stating that there are two basic dimensions to the issue: political – what the communities perceive to be true with regard to noise; and technical – the analytical facts of aircraft noise. He stated that there is a divergence between what the communities and the airports/FAA perceive regarding aircraft noise. He then questioned whether the airports and FAA understand the problem. Do they know where the aircraft fly, what noise levels they produce, or when the 'impact' of the noise occurs? He stated that since noise contours summarize the extent of our knowledge about noise levels and impacts, it is very important that they be accurate. Because of this, Mr. Miller felt that we need to improve our modeling capabilities. This led to a group discussion on how the contour tools can be used to better understand the problem, and how to interface with the communities experiencing problems with aircraft noise.

Emissions

John Rohde opened the session with an overview of NASA's current emissions' programs.

Existing NASA Program Overview

John Rohde reviewed the current NASA programs by briefing the Level 1 Roadmap and the emissions reduction waterfalls. He proceeded through some scenario-based vehicle technologies and noted the fuel burn reduction by area of technology: aerodynamics, structures, propulsion, and systems. Mr. Rohde went through similar process for the emissions (both for CO_2 and NO_x) reduction waterfalls and the effect of technology. He showed the impact of technology on future emissions, the best resulting from the AST Program plus base NASA technology. Mr. Rohde discussed engine, airframe, and materials technologies which might be applied, as well as possible alternative fuels and physics and process modeling.

When asked about the extent of the synergy or discrepancies between noise and emissions goals/roadmaps, it was stated that there are no major disconnects. Although the research for the technologies differs to some extent in that the airframe/wing efficiencies differ for noise and emissions, the main purpose is still to maintain clean engine flow. Mr. Rohde also stated that future programs will consider aerosols for emissions, and that NASA is attempting future programs dealing with the environment as well as economics.

Max CO_2 Reduction of Kerosene Fueled Turbofan Aircraft

Carol Quinn presented the results of the study determining the "ultimate" CO_2 reduction possible for a conventional subsonic transport with turbofans. She discussed how performance was pushed "to the limit" of what is theoretically possible for a turbofan engine. Ms. Quinn then showed CO_2 waterfalls for the 3 different scenarios that she studied; 100 passenger (pax) aircraft, 325 pax and 800 pax, and subsequently demonstrated that with kerosene fuel, the maximum possible reduction in CO_2 would be approximately 82%, which included not only engine, but also airframe improvements. Ms. Quinn concluded that the maximum *practical* emissions reductions for the 3 scenarios were 50%, 58%, and 65%, respectively.

Scenarios for Aviation's Growth: Opportunities for Advanced Technology: "Zero-Emission" Aircraft

Chris Snyder discussed the study of zero-emissions aircraft. He gave the parameters and baseline aircraft used for the study and the fuel concepts included to achieve zero emissions. The fuels were hydrogen, methane, nuclear power, and fuel-cell electric power. He did NOT study battery power due to previous studies, which have found batteries to be extremely heavy for take-off.
Mr. Snyder discussed the above fuels in detail, stating the considerations, then provided a summarization of the results. He said that he would do future research in the area of fuel cells as he saw this as the most feasible option in alternative fuels unless safety was eliminated as an issue for nuclear power.

The issue of using hydrogen as a fuel cell was mentioned. Several people pointed out that there are storage difficulties associated with hydrogen—it would require an extremely large fuselage. When asked about the trade-off with other emissions such as Methane and H_20, Chris stated that since CO_2 and NO_x are currently the biggest concern, that would remain the primary focus. Solar and nuclear fuels were also examined, but solar creates problems during night flying, and nuclear has issues associated with safety and weight requirements. Other hydrocarbon-based fuels are similar to current fuels, so they don't offer much hope for any emissions advantages.

Minimizing the Environmental Footprint of Commercial Aviation

Oren Hadaller gave a presentation on minimizing the environmental footprint of commercial aviation. He talked about the abundance of coal/natural gas in the world and noted that there should be no concern as to the availability of aviation fuel in one form or another. He basically agreed with Mr. Snyder's discussion on alternative fuels, went through some statistics and concluded that more studies should be done with synthetic kerosene, nuclear, hydrogen, and chemical fuel cells (electric). He also concluded that there are adequate petroleum-based fuel resources for aviation, which include synthetic jet fuel. He stated that improved efficiency would minimize the environmental footprint of aviation. He made a point to say that alternative fuels for aviation must be evaluated based on 'resource through end use', not just initial usage in order to evaluate aircraft fuel correctly.

US DOE Hydrogen R&D Program

Dr. Jim Ohi said that the Department of Energy Hydrogen Program conducts applied R&D in hydrogen production, storage, and utilization to enable hydrogen to be a cost-effective energy carrier for utility, building, and transportation applications. He discussed recent world trends and multisector activities, as well as some of the accomplishments for the year 1997, including development of Magnesium/Zinc/Aluminum alloys with properties attractive for vehicle applications and analysis of the cryogenic pressure vessel concept. Dr. Ohi briefed some of the R&D highlights and then some planned 1998 activities. He also discussed the use of hydrogen for subsonic flight, and the preparation of airport scenarios, systems analyses, action-plan development. Dr. Ohi concluded his presentation by discussing the possibility of a joint venture with NASA.

Fuel Cell Propulsion For Commercial Aircraft

Dr. Tom Maloney began his presentation of fuel cells by discussing the various types of fuel cells, which include Proton Exchange Membrane (PEM) Acid Electrolyte and solid oxide electrolyte fuel cells (SOFC). Dr. Maloney then discussed fuels compatibility, as well as some general considerations of fuel cells. He also stated that while hydrocarbon fuels are still the most practical, pollution can only be reduced, not eliminated. Dr. Maloney also discussed the various applications for fuel cells, as well as current development efforts. He discussed the various companies and agencies involved in fuel cell development for areas such as space vehicles (i.e. Gemini and Apollo), and those used in buses. Dr. Maloney then reviewed the technology status of various designs of solid oxide fuel cells. He stated that for aircraft propulsion, PEM will be available earlier than SOFC, although SOFC's are better suited to heavy hydrocarbon fuels than PEM. In closing, he stated that the design and testing of fuel cell systems for commercial aircraft is constrained by time and money, and that full system flight tests are not realistic near-term goals. He emphasized the need to conduct technical and life cycle cost analyses to determine the feasibility of fuel cells, and the need to conduct design and verification tests to answer key questions regarding performance.

Wednesday, July 8, 1998

Mr. Murray reconvened the workshop by reviewing the agenda for the second day's activities.

Interdependency Three Pillar Goals

Howard Wesoky spoke once more about NASA's "Three Pillars," but now added that 8 out of the 10 goals were, in fact, interdependent. He noted that aircraft demand was increasing, as shown by both Boeing and AIA estimates, and that this would have an impact on noise and emissions if nothing was done. Howard discussed the benefits of some of the other goals. He mentioned that the safety goals, if achieved, would save lives and how CNS/ATM would reduce noise and emissions if done efficiently. Other goals were discussed with their resulting interdependencies. He then discussed the NASA noise and emissions roadmaps in general terms. He noted that 2007 and 2022 would require evolutionary and revolutionary technologies respectively. Mr. Wesoky concluded that the goals are interdependent and that it was important for the participants to realize that even if one specific item was not being covered under the noise and emissions goals that it was most likely being covered under another goal.

Operational Technologies to Mitigate the Impacts of Noise & Emissions

Dr. John-Paul Clarke of MIT began this presentation by saying that he and Tom Davis would be sharing the responsibility of briefing. He would be describing the interplay of aviation operations and environmental impact and Tom would be introducing aviation operation decision support tools, which incorporate noise and emissions constraints.

Dr. Clarke discussed the motivations for changing aviation operations to assist the environment. One motivation is that noise is an important factor in the siting and operation of airports. A second is that the noise problem is not just national but global problem. A third is that engine technology has provided significant noise reductions already. A fourth is that operational procedures can provide significant additional noise reductions. Dr. Clarke then presented a chart created by Boeing, which showed the reductions in aircraft noise from 1950 to present. He discussed more motivations, including the limitation by ground-based flight guidance technology and advanced flight guidance technologies, which can improve the applicability and effectiveness of noise abatement procedures. Further emissions-related inducements were presented. John-Paul discussed air traffic control (ATC) and how it could affect emissions of aircraft, indicating that: 1) Airports affect local air quality; 2) Improved operational procedures are gaining importance as means of reducing emissions; and 3) surface and terminal area operations are a primary source of aviation-based ozone creating emissions in lower atmosphere. He stated that minimizing delays and inefficiencies would reduce emissions and constraints on growth of aviation. He felt that automation was required and that creative design for ATC was critical for success. He mentioned systems such as Center TRACON Automation System (CTAS), Final Approach Spacing Tool (FAST), Surface Movement Advisor (SMA), and Expedite Departure Planner (EDP) as possible applicable systems

Tom Davis then proceeded to brief specifically on the histories and benefits of the systems Dr. Clarke previously addressed. He concluded that advanced aviation operations technologies can play a major role in diminishing environmental impact by using advanced decision support tools to enable system users to efficiently and effectively operate, subject to noise and emission constraints; and advanced flight guidance technologies to enable all vehicle classes to operate efficiently while minimizing noise and emission impact.

During the ensuing discussion, Dr. Clarke indicated that they had interviewed pilots during the design of their model, and that the values they used were predicted values obtained from Boeing. He also stated that although they used predicted values, they were about as accurate as ones that could be obtained by measurements. Mr. Davis stated that while Turn Advisory and FAST are available, they are not currently in use by ATC. He also mentioned that while weighting factors are incorporated in real time, there are still some unresolved issues with it.

Atmospherics Science

Don Anderson discussed the assessment of atmospheric effects of aviation. His objective was to provide a scientific basis for assessment of atmospheric impact of supersonic and subsonic aviation, particularly commercial aircraft cruise emissions. His approach was to coordinate the program of aeronautical research to characterize engine emissions and their dispersal from aircraft and atmospheric science research to evaluate effects of aircraft emissions. Don introduced the Steering Committee Charter between NASA, NOAA, and the EPA and mentioned several of the collaborations and agreements with universities in support of the program.

The GE90: A Case Study

Mr. Phillip Gliebe presented a case study on the development of quieter engines through leveraging NASA technologies. He began by stating that the GE 90 is the engine used on the Boeing 777, and represents the application of proven technologies as well as demonstrating new technologies. The GE 90 is a member of the high bypass ratio engine family, which includes the CF6 and CFM56. The GE90 engine design and development was influenced by NASA's Quiet Engine Program in the 1960s, the Quiet, Clean, Short-Haul Experimental Engine Program (QCSEE) of the 1970s, and the Energy Efficient Engine Program and the Unducted Fan (UDF) Engine program of the 1980s. He stated that the key technologies utilized in the GE 90 as a result of these initiatives are the composite fan blade, dual annular combustor, and E^3 high pressure compressor. Mr. Gliebe then discussed the key technologies in greater detail, as well as discussing recent progress in the reduction of engine noise utilizing the GE 90. He ended his briefing by summarizing the influence of NASA funded noise research on the GE 90 engine design, and stated that new and derivative product engines will also benefit from NASA funded technology. He also mentioned benefits of integrating academia into the partnership, as they contributed substantial theoretical research on the design of the GE 90, and that the synergy among NASA, industry, and academia often yields the best technological improvements.

The Dual Annular Combustor (DAC): A Technology Readiness Case Study

Will Dodds presented the case study on the dual annular combustor. He initiated his presentation by stating that the change to the dual annular combustor was based on a NASA technology program. He then described the process by which emissions such as NO_x, CO_2, water, and sulfur aerosols are formed, in order to explain how the design of this combustor reduces those emissions. Mr. Dodds then described the design of the combustor, and explained the history of its design, which dates back to the first DAC engine program, run by NASA in 1974-78. Mr. Dodds reviewed the factors that affected product transition, among them the fact that key technical issues were not addressed early enough in concept development. He also discussed the key factors that aided product transition. In closing he discussed the lessons learned from the DAC program. When asked why the dual annular combustor engine is not used more widely throughout the airline fleet, Ray Brown indicated that the increased maintenance of the DAC vice the single annular combustor, along with the lack of operational benefit, makes it a less attractive choice for airlines.

Logistics

Afternoon Breakouts
Howard Wesoky introduced this item by reviewing the questions formulated at the first workshop:

- What are the impacts of aviation noise and emissions on the environment?
- How do you believe these may affect the growth of aviation?
- Must the growth of aviation lead to increased environmental impact?
- What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

He stated that many of the answers to these questions have been discussed during this and preceding workshops and that this Workshop would now look at the Three Pillar Goals, NASA's research strategy, its Roadmaps, and how to move forward. With that he turned the meeting over to Frank Murray.

Mr. Murray told the Group that they were now going to break into three subgroups and address the questions contained in the agenda for this portion of the Workshop and then report back to the plenary on Thursday morning. He mentioned that Bob Cuthbertson would lead the Industry Group, Ray Brown, the Operator Group, and Betty Ann Kane, the NGO/Communities Group. He stressed that Federal employees could attend any of the sessions but only as observers and, if asked to leave at some point, they could enjoy the local Monterey area.

The three Breakout Groups met for the rest of the afternoon to formulate their answers to the following questions.

Goals

- Will the attainment of the goals satisfy your environmental concerns?

Research Strategy

- Does the NASA strategy appear to be appropriate?

Road Maps

- Have the Road Maps reached an appropriate balance between near term and far term goals?
- Have the Road Maps properly leveraged other government and industry programs?
- What technologies need to be pursued as soon as possible?

Moving Forward

- What form of continuing communication with NASA would be of value to your organization?
- In what way would you be willing to participate in the pursuit of these research objectives?

Mr. Murray also asked each of the Groups to consider what kinds of information would be of interest to them in regard to NASA feedback.

Thursday, July 9, 1998
Results of Breakouts

Plenary Meeting – Report of the Feedback Groups and Discussion

Beginning with the Industry Breakout Group, each of the breakout groups presented their reports to the entire workshop. These presentations are also available on the website. A summarization of the reports is provided below.

Goals

- *Will the attainment of the goals satisfy your environmental concerns?*

There seemed to be a consensus (2 out of 3) that YES, the attainment of the goals would satisfy environmental concerns, but there were qualifications to that question by all three groups. Industry said that affordability, safety, and emissions goals must be simultaneously addressed with noise. Operators said that there is a need for more short-term/intermediate goals/solutions. NGO/Communities questioned whether the measurement tools used were adequate for NO_x and thought that a clearer connection between NASA's research goals and the real-world impact was necessary to satisfy environmental concerns.

Research Strategy

- *Does the NASA strategy appear to be appropriate?*

Generally, all three groups felt that the NASA strategy appeared to be appropriate, however, there was some question during the breakouts as to what exactly NASA's strategy was. Industry assumed that the gap analysis defined the strategy and that system studies should guide revolutionary concepts for noise reduction. The operators felt that a better understanding/definition of emissions and criteria would help resolution as well as advocacy by interest groups for assisted funding. The NGO/Community group thought that NASA's strategy should parallel research for market acceptance. They thought that it was important that noise and emissions strategies were worked concurrently to cover all bases.

Road Maps

- *Have the Road Maps reached an appropriate balance between near term and far term goals?*

Industry felt that NASA needed to stress continuous parallel evolution of quieter components and airplanes. On emissions, industry thought that the near-term focus should be on carbon fuel. Operators thought that emissions should focus on more near-term work, within 5 years. They felt that noise was balanced appropriately. NGO/Community said that maybe 30-40 year goals should be added, but in addition to short-term goals, not in place of them.

- *Have the Road Maps properly leveraged other government and industry programs?*

Industry said that there was opportunity for excellent flow from the AST Program. There must be ties with aerodynamics, structures, CNS/ATM, etc, in the noise area. Emissions, they saw as leveraged well. Operators recognized a disconnect between emissions and noise with other activities like CNS/ATM. They thought that there should definitely be some obvious interdependency. NGO/Community group thought that NASA should take a lead in leveraging other government and industry programs, that they have the support of those present at the workshop.

- *What technologies need to be pursued as soon as possible?*

Industry saw that the roadmaps did an adequate job of defining those technologies that should be pursued as soon as possible. NASA just needs to follow that roadmap, keeping to the idea of improved efficiencies. Operators thought that local air quality modeling and improved noise models were a good investment. NGO/Community said that AST was an excellent program to model and that maybe dual annular combustors should be seriously considered.

Moving Forward

- *What form of continuing communication with NASA would be of value to your organization?*

Industry discussed how the AST Program was a good model to use for future programs. It provided a method for cooperation/coordination. Operators thought that a report every 6 months showing progress would be a good way to keep in touch with the program. The NGO/Community felt that two-way exchange of information and ideas would help as well as continuous update of the existing website.

- *In what way would you be willing to participate in the pursuit of these research objectives?*

Industry saw that forming a focus group and technical working group/steering committee would be one way to participate in pursuit of research objectives. Operators gave a list of way to participate including educational outreach, critiques, data providing, meetings, etc. NGO/Community was willing to provide opinions and review proposed programs, provide public awareness of related programs and help educate decision-makers.

Impressions & Observations

Cindy Newberg and Donald Sutkus were again asked to give their impressions of the workshop. Some of the lessons learned are listed below:

- The blending of presentations and discussion groups was effective, particularly in Cleveland.
- NASA was responsive to requests for supporting information (i.e. DOE hydrogen talk), particularly in Monterey.
- The off-site (from D.C.) locations were useful, and resulted limited distractions and neutral territory.
- Between the first and third workshop, NASA's role and participation increased greatly… to what extent was this a pro or con?
- A clear picture of the relationship of our work to other Pillar Goals work (i.e. HSCT connection) was lacking.
- The workshops were and excellent forum for building relationships with stakeholders in the noise/emissions field.
- Breakout groups by affiliation (I.e. NGO, industry,…) were effective but too late to allow adequate exchange of results.
- Should have had a non-NASA federal employee group and an academic group.

Don Sutkus presented the outstanding issues:

- Three Pillar Goals are given in terms of **implementation** time frames … we need more discussion on this. He suggested Workshop IV in Hawaii.
- How far should TRL6 take you toward a finished product? Should NASA go further?
- What will the mechanism of giving workshop participants feedback on the results of their efforts be?
- Has workshop process been a success from NASA's standpoint?
- What should the mechanism be for reevaluating goals if they are found to be unsatisfactory (at this workshop or in the future)?
- Is there a need to define mechanisms for continuing this workshop dialogue?

Mr. Sutkus also stated that while most participants feel that the workshops were worthwhile and successful, it is important to know if the workshop process has been a success from NASAís viewpoint. In closing, Don reiterated the importance of maintaining the open dialogue among the various interest groups that were started during the workshop process.

Closing Comments

Frank Murray stated that he was extremely pleased with this Workshop activity. He hoped that the lines of communication, which were opened in this process, would continue to remain open. He thought that now the ball had been passed to NASA to maintain this open communication. Some of the key points made at this workshop were that there needed to be more Federal interagency coordination, improved efficiencies would help achieve some near term goals, better modeling was needed and an increased emphasis on a total systems approach was necessary. Frank stated that he had enjoyed his role and that the SAIC staff had done a fine job in orchestrating these workshops. He wished all participants well in their future endeavors.

Howard Wesoky also thanked the SAIC staff and all of the workshop participants. He then shared his thoughts on where he thought the workshop process had been and what had been accomplished. He showed the workshop process schematic once more and reviewed the last workshop objectives. Mr. Wesoky saw the review of the roadmaps as complete for now, but that it was an ongoing process. He anticipated that NASA would move forward with their roadmaps and the technologies that were necessary as soon as possible. He saw the way forward as dealing with annual budget cycles, whether it be NASA's, Congress' or the President's, advocacy with all of the organizations NASA has become familiar with, and implementation via R&D partnerships and advice from panels. He showed the Technology Readiness Level (TRL) Chart and said that the transition between TRL 6 and 7 was sometimes not clear and that NASA needed industry's help to achieve that transfer of technology for implementation.